Human Evolution and Migrations 2023

Who invented stone tools? A great surprise from Kenya

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Up to now the earliest stone tools are objects dated to about 3.3 Ma (Late Pliocene) found in the Turkana basin of Kenya in 2015. They are sharp-edged pieces of rock that seem to have been made simply by striking two lumps of rock together (see: Stone tools go even further back; May 2015). These Lomekwian artefacts are similar to the basic tools made today by some chimpanzees in parts of Africa. Their age matches that for the earliest known animal bones that show signs of having meat cut from them, which were unearthed in Dikika, Ethiopia (see: Another big surprise; September 2010) which, like the Lomekwian tools, are not accompanied by tools or hominin remains. The earliest tools associated with members of the genus *Homo* are significantly more sophisticated. They were found in close association with *H. habilis* at what seems to have been a well-used butchering site, dated at 2.0 Ma, in Tanzania's Olduvai Gorge, hence their designation as the Oldowan 'industry'. The Oldowan 'tool kit' includes choppers and blades deliberately shaped to be wielded by hand and made by striking large cobbles with distinctive hammer stones. Earlier tools with this level of deliberate crafting come from the 2.6 Ma Ledi-Geraru site in the Afar Depression of NE Ethiopia but with no sign of their makers.

Oldowan tools used for pounding and cutting from Nyayanga, Kenya (Credit: Thomas Plummer, James Oliver and Emma Finestone/Homa Peninsula Paleoanthropology Project/SWNS)

The presence of Oldowan tools has now been pushed further back, by about 400 ka, thanks to excavations in Late Pliocene sediments at Nyayanga on the shore of Lake Victoria in western Kenya by Thomas Plummer of Queens College in New York State, USA, and his numerous collaborators from the US, Germany, the UK, China, Italy, Australia, Kenya, South Africa and Poland (Plummer, T.W. and 31 others 2023. Expanded geographic distribution and dietary strategies of the earliest Oldowan hominins and Paranthropus. *Science*, v. **379**, p. 561-566; DOI: 10.1126/science.abo7452). Their work also expands the range of Oldowan culture by about 1300 km. The Nyayanga site yielded over 300 artefacts that closely resemble the previously known range of Oldowan tool shapes. Their makers struck flakes from suitable corestones – made of rhyolite, quartz and quartzite – and trimmed them by more intricate means. They seem to have been used to cut up mainly hippo and buffalo, bones of which bear clear cut marks, but had other uses. Analysis of the wear on tool surfaces not only show signs of butchery, but also processing of plant tissue by pounding; the latter resulted in pitting and polishing of tools that seem to have been used many times. Stable-isotope analysis of the bones and animal teeth suggests that in the Pliocene Nyayanga was a grassy and partly wooded savannah close to a substantial water body needed by hippos.

Reconstruction of a Paranthropus head (Credit: Jerry Humphrey, Pinterest)

The 'great surprise' is that the only hominin remains associated with the site are two damaged molar teeth. They are so large that their most likely source was a species of *Paranthropus*.Paranthropoids have long been considered to be a gorilla-like, 'robust' branch of australopithecines. Their large cranial crests anchoring jaw muscles and enormous

teeth were reckoned to indicate a diet of tough vegetation – the discoverer of the first specimen of *P. boisei* dubbed it 'Nutcracker Man' – although the wear on individual teeth suggests otherwise. But there is no reason to suppose that they could not eat meat. They survived australopithecines by more than a million years to cohabit the East African savannahs with *H. ergaster* until about 1 Ma ago.

Lead author Thomas Plummer wonders if paranthropoids would have needed tools because they had the largest jaws and teeth of any hominin. But had his team found close association with smaller *H.habilis* teeth would he have held a similarly negative view? There is evidence from younger sites in South Africa that paranthropoids used a wide diversity of bone tools and may even have been among the earliest fire users. So why the negativity about stone tools? To paraphrase Ali G, 'Is it because they is ugly?'

See also: Devlin, H, Discovery of 3m-year-old stone tools sparks prehistoric whodunit. *The Guardian*, 9 February 2023

Neanderthal elephant hunters

PUBLISHED ON *February 4, 2023Leave a comment*

In the 1980s miners in the Neumark-Nord area of Saxony-Anhalt, central Germany uncovered an extensive assemblage of animal bones and stone tools in opencast 'brown coal' (lignite) workings. Archaeologists working over a ten-year period recovered bones from an estimated 70 straight-tusked elephants (*Palaeoloxodon antiquus*), as well as many other large herbivores, while huge bucket-wheel excavators advanced through the deposit. Most of the elephants were adult males, some preserved as entire skeletons others as disarticulated bones. Weighing as much 15 tonnes – equivalent to ten medium SUVs – and standing up to 4 m high at the shoulder, they were twice as large as the biggest modern African elephants and had far longer legs. Being so tall they could browse vegetation up to 8 metres above the ground surface using an 80 cm tongue as well as a long trunk and their huge tusks.

The lignite deposits formed in marshes and shallow lakes that occupied low-lying depressions left in the wake of retreating glaciers during the last (Eemian) interglacial (130 to 115 ka ago). The warming encouraged temperate forest to extend much further north than it does today. The fauna too would have changed substantially once the ice sheets began to retreat. For instance, mammoths that grazed low tundra vegetation during the preceding ice age disappeared from Central Europe to be replaced by straight-tusked elephants migrating from much further south that had plenty of trees, shrubs and grasses to feed on, as did other herbivores. So the central European plains teemed with big game. The marshes and lakes had little outflow and became depleted in oxygen so that dead vegetation built up to form extensive peat deposits: just the conditions for organic preservation.

Artistic impression of Neanderthal elephant butchery site (Credit: Tom Bjorklund, Science)

The Neumark-Nord sites yielded literally tonnes of fossils, including 3400 elephant bones. But these were not simply the remains of animals that had become bogged down and died of exhaustion. Sabine Gaudzinski-Windheuser and Lutz Kindler of the Johannes Gutenberg University of Mainz, Germany and Katherine MacDonald and Wil Roebroeks of Leiden University, Netherlands have examined every bone for signs of post-mortem modification by humans (Gaudzinski-WindHeuser, S. *et al*. 2023. Hunting and processing of straight-tusked elephants 125.000 years ago: Implications for Neanderthal behaviour. Science Advances, v. **9**, article add8186; DOI: https://doi.org/10.1126/sciadv.add8186). Some bones are so large as to require a forklift to shift or turn them in the laboratory. Most of the bones bear deliberate cut marks made by stone blades: far more than signs of gnawing by carnivores. Neanderthals had got to them before scavengers. The density of cuts and gouges suggests that almost every scrap of meat and fat had systematically been harvested from the corpses, even the fat-rich feet and brains. The sheer number of cuts needed to skin and deflesh the elephants strongly suggests that their meat was fresh: rotten meat could simply have been pulled from the skin and bone quite easily. Little was left for scavengers to gnaw.

Each elephant would have yielded enough meat and fat for an estimated 2500 portions, each with a calorific value of around 4000 kcal. To fully butcher each beast and then to dry and/or smoke the produce can be estimated – by comparison with such work on a modern African elephant – would take around 1500 person hours. To achieve that would require 3 to 5 days of very heavy labour by 25 people. Some means of preservation would have been needed, unless hundreds of people had scoffed the lot at one or two sittings. The authors consider the bounty to imply that a considerably larger collective of Neanderthals than the previously estimated ~25 per band probably benefitted from a single elephant, whether it was eaten on the spot or preserved in some way and either carried off or cached. But 70 elephants …?

The geographic context suggests a pile of corpses built up in lignite close to or on a lake shore had accumulated over a lengthy period. Using likely sedimentation rates backed by counting of annual tree rings from stumps in the lignite the authors estimate that the pile formed over about 300 years at a rate of one kill every 5 to 6 years. But this site is one of several found in the Neumark-Nord area, albeit not quite so large, and there are probably more, either remaining buried or destroyed by the brutal lignite mining technique. Taking on a herd of animals would be far more risky than hunting individuals. This is where the sex of the elephant remains gives an idea of the hunters' strategy. Those that could be sexed – about 23 – were all adult males that were estimated to be from 20 to 50 or more years old. By analogy with African elephants, adult male are generally solitary, only joining herds of females and offspring when one or more is at oestrus. Male straight-tusked elephants were more than twice the mass of adult females and when keeping themselves to themselves would have been a safer and more profitable target than females and juveniles in a herd. Solitary males would have been easy to approach, being confidant that their size would deter direct predation by the largest carnivores, such as lions. In a peaty swamp, simply driving an individual into deep mud would bog it down to be dispatched by spear thrusts. The earliest known thrusting spears have been unearthed in similar lignite beds 200 km away.

This study adds to growing understanding of Neanderthal culture. It suggests that they were not just opportunistic and wandering foragers but regularly combined resources to focus on a specific, very high-value prey. Maybe that was restricted to the special peat-swamp environment of what is now central Germany, but it speaks of an ability to plan and orchestrate spectacular communal events. And they performed such feats again and again. They were the masters of Europe through three of four glacial-interglacial cycles.

How humans might have migrated into the Americas

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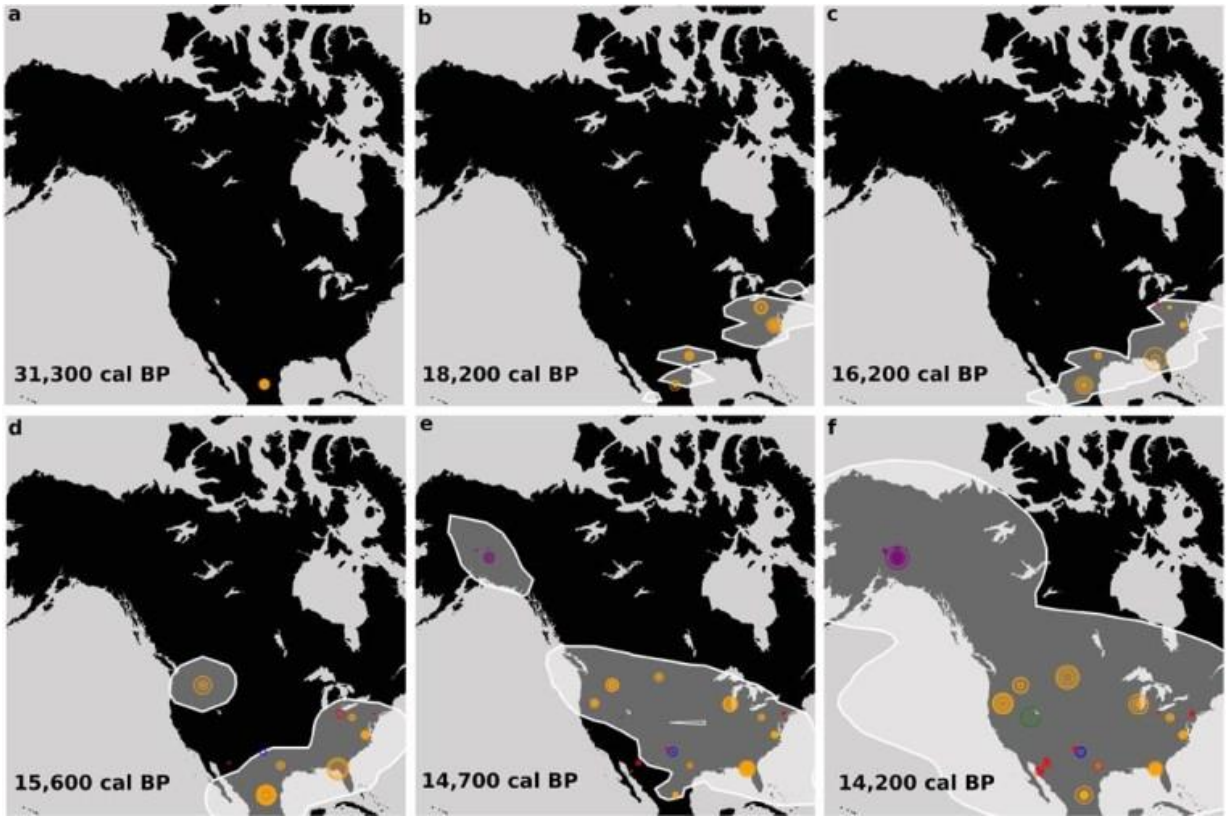
When and how humans first migrated into the Americas are issues that have exercised anthropologists for the last two decades, often sparking off acrimonious debate. In the 20th century both seemed to well established: hunters using the celebrated Clovis fluted spear blades arrived first, no earlier than 13 ka ago. The Beringia land bridge across what is now the Bering Strait was exposed by falling sea level as early as 30 thousand years ago in the lead-up to the last glacial maximum (LGM) to link eastern Siberia and Alaska. However, ice sheets expanding to the south-west of the main area of glaciation on the Canadian Shield barred passage through Interior Alaska and NW Canada. Only around 13 ka had a N-S ice-free corridor opened through the mountains during glacial retreat. Nevertheless, humans had entered Alaska at least ten thousand years earlier, during the LGM, to occupy caves in its western extremity: Alaska was habitable but they were stuck there.

In the early 21st century, it became clear that the 'Clovis First' hypothesis was mistaken. Sediments in Texas that contained Clovis blades were found to be underlain by those of an older culture, reliably dated to about 15.5 ka. Furthermore, analysis of the DNA of all groups of native Americans (north and south) indicated a last common ancestor in Siberia more than 30 ka ago: they descended from that ancestor *outside* of Asia. More recently excavated sites in Mexico and Chile point to human populations having reached there as early at 33 ka (see: Earliest Americans, and plenty of them; July 2020), and there is a host of pre-Clovis sites in North and Central America dating back to 18.2 ka. Such ancient groups could not have walked from the Beringia land bridge because the present topographic grain in the Western Cordillera would have been blocked by ice since about 25 thousand years ago. The only viable possibility was that they followed the Alaskan coast to move southwards, either in boats or over sea ice.



Dated pre-Clovis sites in Mexico and North America and possible expanding distribution of people from 31.3 to 14.2 ka (Credit; Becerra-Valdivia and Higham; Extended Data Fig. 4)

A new focus on *when* such journeys would have been feasible was published in February 2023 (Praetorius, S.K *et al*. 2023. Ice and ocean constraints on early human migrations into North America along the Pacific coast. *Proceedings of the National Academy of Science*, v. **120**, article e2208738120; DOI: 10.1073/pnas.2208738120). One advantage of moving along the coast is that, though it would be pretty cold, the warming effect of the Pacific Ocean would make it more bearable than travelling inland, where winter temperatures even today regularly reach -50°C. More important, there would be no shortage of food; fish, marine mammals and shellfish abound at the ice margin or onshore, at any season. But a coastal route may not have been possible at all times during the period either side of the LGM. Large glaciers still reach the ocean from Alaska and there is little more perilous than

crossing the huge crevasse fields that they present. Boating would have been highly dangerous because of continual calving of icebergs from extensive ice shelves. Moreover, the Alaska Coastal Current flows northwards and would likely have sped up during episodes of glacial melting as the current is affected by fresh water influx. Yet there may sometimes have been episodes of open water at the ice front frozen to relatively flat sea ice in winter. That would making boat- or foot travel relatively safe. Sea ice would also make glacier-free islands accessible for encampments over the harsh winters or even for hundreds of years, with plenty of marine food resources.

Summer Praetorius of the US Geological Survey and colleagues from Woods Hole Oceanographic Institution, Oregon State University, and the Universities of California (Santa Cruz) and Oregon have attempted to model conditions since 32.5 ka ago in coastal waters off Northwest America. They used simulations of the behaviour of the Alaska Coastal Current during varying climate conditions before and during the LGM, while glaciers were in retreat that followed and during the Holocene. Their modelling is based on the effects of changing sea level and water salinity on general circulation in the Northern Pacific. The relative abundance of sea ice can be tracked using variation in an alkenone produced by phytoplankton that wax and wane according to sea-surface temperature and sea-ice cover. The other input is the well-documented changing extent of continental glaciation in Alaska and the Yukon Territory. Based on their model they estimate that the most favourable environmental conditions for coastal migration occurred just before the LGM (24.5 to 22 ka) and between 16.4 and 14.8 ka during the initial stages of warming and extensive melting of ice sheets. The Alaskan Coastal Current probably doubled in intensity during the LGM making the use of boats highly dangerous

By 35 ka ocean-going boats are known to have been used by people in northern Japan. Traversing sea-ice was the way in which Inuit people occupied all the Arctic coastal areas of North America and Greenland during the last five thousand years, and is the form of travel favoured by the authors. It is not yet possible to prove and date such coastal journeys because campsites or settlements along the coast would now be inundated by 100 m of post-glacial sea-level rise. Yet such migration was necessary to establish settlements at lower latitudes in North America and Mexico in the period when overland routes from Beringia were blocked by ice sheets. By 32.5 ka falling sea level probably made it possible to cross the Bering Strait for the first time and for the next 7.5 ka an ice-free corridor made it possible for the rest of North America and points further south to be reached on-foot from Alaska. That window of opportunity might have allowed humans to have reached Mexico and South America, where the earliest dates of occupation have been found. But many of the early sites across North America date to the period (25 to 13 ka) when overland access was blocked. Of course, those sites might have been established by expansion from the very earliest migrants who crossed the Beringia land bridge and took advantage of overland passage before 25 ka. But if later migrants from Asia *could* follow the coastal route, then it seems likely that they did. Later Inuit spread along the shores of the Arctic Ocean since 5000 years ago probably with a material culture little different from that of the earlier migrants from Siberia.

Origin of the genus Homo: a Paranthropus link?

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Reconstruction of a Paranthropus head (Credit: Jerry Humphrey, Pinterest)

Paranthropoids had large, broad teeth and pronounced cheekbones plus a bone crest on the top of their skulls that were the attachments for powerful jaw muscles, much as in modern gorillas. Unlike gorillas they were definitely bipedal and were more similar to australopithecines. They have been called 'robust' australopithecines but they were not significantly taller or heavier. The first to be unearthed at Olduvai, Tanzania in 1959 (*Paranthropus boisei*) was dubbed 'Nutcracker Man' by its finder, and many have implied that paranthropoids' teeth and powerful jaws were signs of a vegetarian diet that needed a lot of chewing. Yet their teeth do not show the microscopic pitting associated with living primates that eat hard plant parts and nuts, or the heavy wear that results from eating grasses. They probably ate soft plants, such as semi-aquatic succulents or tubers, but meat-eating that causes little dental wear cannot be ruled out. Some specimens are associated with long bones of other animals whose ends are worn, suggesting that they may have used them as tools for digging. Plant remains found at paranthropoid sites suggests that they inhabited woodland, together with coexisting australopithecines. They were around in the form of three successive species from 2.9 to 1.2 Ma, outlasting australopithecines. The later paranthropoids coexisted with *Homo habilis* and *H. erectus*: they were clearly just as successfully adapted to their surroundings as were early humans.

In early 2023 evidence was published that associated Oldowan stone tools with remains of *Paranthropus*, together with deliberately defleshed and cut bones (see also): though association is not proof of a direct link. Interestingly, the hand of a *P. robustus* found in the Swartkrans cave system in South Africa is consistent with a human-like precision grip, i.e. it had an opposable thumb. Swarkrans also yielded the earliest evidence for the deliberate

use of fire about 1.5 Ma ago, associated with remains of both *P. robustus* and *H. erectus.* All this suggests that a case could be made for paranthropoids' being human ancestors – supporting evidence has just been published (Braga, J. *et al*. 2023. Hominin fossils from Kromdraai and Drimolen inform *Paranthropus robustus* craniofacial ontogeny. *Science Advances*, v. **9**, article eade7165; DOI: 10.1126/sciadv.ade7165).

Fossil-bearing breccias beneath the floor of the Kromdraai cave in the Cradle of Humankind World Heritage Site 45 km NW of Johannesburg, South Africa yielded the first near-complete *P. robustus* skull in 1938, another being found in cave breccias at the nearby Drimolen quarry. These deposits also contained remains of four infants assigned to the species, whose teeth and cranial parts were at different stages of juvenile development (ontogeny). José Braga of the University of Toulouse, France and co-workers from South Africa and the USA compared this growth sequence with those teased out from immature specimens of *Australopithecus africanus* and early *Homo*.Their tentative conclusion is that *Paranthropus robustus* is more closely related to early humans than to australopithecines of the same stratigraphic age.

Skull of a probable adult female *P. robustus* (left) with that of *H. habilis* (centre) and *Au. africanus* (right). Credits: all from Wikipedia pages

So, it now seems possible that paranthropoids are not 'robust' australopithecines in an acceptable, taxonomic sense. Their closer resemblance in early development to early humans, together with their association with early stone tools used for defleshing prey animals, together with evidence for possible their use of fire, further strengthens their candidacy for an ancestral link to humans. The best preserved skulls of *Homo habilis* and a female *P. robustus* (males of that species show the distinctive saggital crest) do show close similarities, that of a roughly contemporary *A. africanus* having distinctly wider cheeks than both. All three species were in life probably of much the same weight and stature (30 to 40 kg and 110 to 130 cm) but *H. habilis* had a significantly larger brain volume (500 to 900 cm^3) than the other two (each ~450 cm^3). However, this isn't *proof* that the genus *Homo* evolved

from a paranthropoid ancestor. That would require genetic evidence, unlikely to be extracted from specimens because DNA seems to degrade more quickly under the conditions of the tropics than at high latitudes. Debate on ultimate human origins will probably be endless. Perhaps it would make more sense simply to accept that early humans weren't the only 'smart kids on the palaeoanthropological block', one of which left no issue after 1.2 Ma ago.

See also: Handwerk, B. 2023. Who made the first stone tool kits? *Smithsonian Magazine,* 8 February 2023, article 180981606

Extraction of ancient human DNA from artefacts

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The Denisova cave in southern Siberia is now famous for the evidence that it has provided for Neanderthals and Denisovans and their interbreeding based on DNA recovered from their bones, even a tiny finger bone of the latter. Indeed we would not know of the former existence of Denisovans without such a clue. Scientists at the Max Planck Institute for Evolutionary Anthropology in Leipzig, responsible for both breakthroughs, also pioneered the extraction of hominin DNA from soil in the cave. Now they have refined the intricate extraction of genetic material to such an extent that detailed hominin DNA sequences can be analysed from ornaments worn by ancient people, in much the same manner as applied in forensic studies of crime scenes (Essel, E. and 22 others 2023. Ancient human DNA recovered from a Palaeolithic pendant. *Nature*, early release 3 May 2023; DOI: 10.1038/s41586-023-06035-2).

Elk-tooth pendant found at Denisova cave, before cleaning and DNA extraction (top) and after the 'washing' procedure (bottom). Credit: Essel et al., Fig 1.

Russian archaeologists who continue to work at Denisova cave found a pierced pendant made from the tooth of a Siberian elk or wapiti during *the 2019* field season. It was sent to Leipzig, where the palaeogenetics team had been trying to extract the DNA of whoever had worn personal artefacts found in French and Bulgarian caves. Their efforts had been unsuccessful, but such an object from Denisova clearly spurred them on. When someone wears next to the skin objects made of porous materials their sweat and the DNA that it carries seeps into the pores. If the materials decay very slowly, as do bone and especially teeth, genetic material can, in principle be extracted. But crushing up important ancient objects is not an option: for such rarities the extraction has to be non-destructive. It can only be done by 'washing' it in reagents that do not themselves break down DNA. Elena Essel and her many colleagues experimented with many 'brews' of reagents and repeated immersion at steadily rising temperature (up to 90°C). This releases genetic material in a stepwise fashion, allowing separation of contaminants in the host sediment from that which had penetrated into the tooth's pores from whoever made the pendant and the wearer, and the animal from which it came

Analysis of the recovered material yielded elk mtDNA, which was compared with that from four other ancient elks of known ages. This suggested that the elk had lived between 19 and 25 ka ago, thereby indirectly dating the time when the pendant was made and worn. A surprisingly large amount human DNA showed that the wearer was a female who was genetically allied with ancient anatomically modern humans who lived further east in Siberia at about that time.

Obviously this astonishing result opens up a wide vista for archaeology, though not from Palaeolithic burials, which are extremely rare. But artefacts of various kinds are much more common that actual human remains. Because the technique is non-destructive museums may be more willing to make objects in their collections available for analysis. Maybe the approach will be restricted to porous bone or tooth ornaments worn for long periods by individuals. Yet stone tools that were handled continually could be a more important target, depending on the rock from which they were made and its porosity.

See also: Lesté-Lasserre, C.. DNA from 25,000-year-old tooth pendant reveals woman who wore it. *New Scientist*, 3 May 2023.

Early modern human fossils from a Laotian cave and the eastward 'out-of-Africa' migration

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Finding human fossils in SE Asia is rare because its tropical climate generally results in decomposition of bones. Up to now the oldest known anatomically modern human (AMH) found beyond the Middle East is from Australia and has been dated to 65 ka. Other, less convincing candidates for the earliest appearance of AMH in Asia are scattered teeth found in Chinese caves that yielded dates of up to 139 ka: their assignment to AMH and the reliability of their dating are disputed. Now a large team of scientists from the USA, Germany, Australia, South Africa, France, Denmark and Laos have unearthed convincing but fragmented AMH bones among a jumble of diverse animal fossils in sediment flooring Tam Pà Ling cave in northern Laos (Friedline, S.E. and 30 others 2023. Early presence of *Homo sapiens* in Southeast Asia by 86–68 kyr at Tam Pà Ling, Northern Laos. *Nature Communications*, v. **14**, article 3193; DOI: 10.1038/s41467-023-38715-y). Several dating techniques reveal ages of the AMH samples that range from 46 to 77 ka, and potentially as far back as 86 ka. It is conceivable that the oldest are from the population that subsequently reached Australia. Far to the west of Laos in Greece, Israel and Arabia an earlier AMH presence goes back as far as 90 to 210 ka. Moreover, palaeoclimatic studies suggest many opportunities for eastward migration since 290 ka ago that AMH emigrants may have exploited. Once beyond regions around Arabia and the Gulf, which were periodically hyperarid, the journey to the rest of Asia was probably continuously habitable throughout the last two glacial-interglacial cycles.

Entrance to Tam Pà Ling cave in northern Laos (credit: Demeter et al.; Fig S1)

Another aspect of the AMH record in southern and SE Asia is that the individuals represented seem to have been anatomically very varied (Demeter, F. *et al.* 2023. Early Modern Humans and Morphological Variation in Southeast Asia: Fossil Evidence from Tam Pa Ling, Laos. *PLOS ONE*, v. **10**, article e0121193. DOI:10.1371/journal.pone.0121193). This may suggest that migration was by significantly different groups at different times. Oddly, the earliest known examples have more 'modern' characteristics than younger ones that appear somewhat 'archaic'. The age of the fossils conflicts with the 60 ka age reconstructed from genetic evidence for the main diffusion across Eurasia and Australasia. One possibility is that there were several pre-60 ka migrations, descendents of these early populations having been replaced or assimilated by a later, larger numbers of AMH migrants. At 74 ka the Sumatran Toba supervolcano erupted about 2,800 km^3 of ash to blanket a vast area and cause global cooling that could have more than decimated migrating AMH groups. Alternatively the 60 ka 'genetics' date is not correct, as suggested by the minimum date of 65 ka for the earliest Australians. Such a conflict of evidence will surely spur further excavation: as one researcher observed about Laos, 'There are thousands of caves to explore'.

See also: Coleman, J. 2023. Laos cave fossils prompt rethink of human migration map. *Nature*, v.**618**; DOI: 10.1038/d41586-023-01903-3; Ashworth, J. 2023. Fossils reveal early modern humans in southeast Asia 77,000 years ago. *Natural History Museum's Discover*, 15 June 2023.

When and why did the North American Pleistocene megafauna collapse?

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The US city of Los Angeles, originally known as *El Pueblo de Nuestra Señora la Reina de los Ángeles* (The Town of Our Lady the Queen of the Angels), was founded in 1781 by 44 Spanish settlers. It remained a small cattle-centred town after the annexation of California from Mexico by the USA in 1847. Once it was reached by the transcontinental Southern Pacific railroad in 1876 it had the potential for growth. But it took the discovery of oil within its limits in 1892 for its population to increase rapidly. The Los Angeles City Oil Field became the top producer in California with 200 separate oil companies crammed cheek by jowl by 1901. Now only one remains, producing just 3.5 barrels per day. That crude oil was there for the taking was pretty obvious as bitumen seeps had long been exploited by native people and the original Spanish colonists. The oilfield was developed near one such seep: the Rancho La Brea tar pits.

Rancho La Brea tar pit and derricks of the Los Angeles City Oil Field in 1901

By 1901 perfectly preserved bones of a huge variety of animals – 231 vertebrate species – as well as plants and invertebrates began to be collected from the continually roiling pond of bitumen. Thousands of specimens have been collected since then, both predators and prey of all sizes. Famous for mastodons and sabre-toothed cats, La Brea is a repository of almost the entire western Californian fauna through much of the Late Pleistocene: before about 100 ka the area lay beneath the Pacific Ocean. Tar pits are traps for unwary animals of any kind, especially as shallow water often hides the danger. Carnivores seeking easy, abundant food end up trapped too.

Because of the anaerobic nature of bitumen, bacterial decay is suppressed. Many of the bones still contain undegraded collagen: the most abundant protein in mammals, which can be dated using the radiocarbon method. So, despite the lack of stratigraphy in the tar pits, it is possible to track the history of the ecosystem by painstaking dating of individual fossils (OKeefe, F.R and 18 others 2023. Pre–Younger Dryas megafaunal extirpation at Rancho La Brea linked to fire-driven state shift. *Science*, v. **381**, article eabo3594; DOI: 10.1126/science.abo3594). Robin OKeefe and colleagues dated 169 specimens of eight large mammal species most commonly found in the bitumen: sabre-toothed cat (*Smilodon fatalis*); dire wolf (*Aenocyon dirus*); coyote (*Canis latrans*); American lion (*Panthera atrox*); ancient bison (*Bison antiquus*); western horse (*Equus occidentalis*); Harlan's ground sloth (*Paramylodon harlani*); and yesterday's camel (*Camelops hesternus*).

The authors focussed on precisely dated specimens spanning the 15.6 to 10.0 ka time range. This would allow the disappearance times of individual species to be compared with stages in the rapid change in the Californian climate during post glacial maximum warming, those during the Younger Dryas abrupt cooling (12.9 to 11.7 ka) and the earliest Holocene warming that succeeded it. The first to go extinct were the camels and giant sloths about 13.6 ka ago. At 13.2 ka the other mammals declined very rapidly, the two remaining herbivores vanishing more quickly than the four predators. By 12.9 ka the only surviving species of the chosen eight was the coyote. So seven members of the Pleistocene mammalian megafauna became extinct *before* the onset of the Younger Dryas cold millennium.

Part of the team examined pollen from a core through sediments deposited in a lake 100 km south of La Brea. They found that flora, and probably climate, had not changed at the time of camel and sloth extinctions around 13.6 ka. However a 300 year period between 13.2 and 12.9 ka witnessed a collapse in deciduous tree species while conifers, grasses and drought-tolerant shrubs increased. A woodland ecosystem had been replaced by semi-arid chaparral. Another feature of the lake-bed sediments was that charcoal fragments increased explosively during that 300-year episode that ended both the woodland ecosystem and the megafauna that exploited it: undoubtedly three centuries of regular wildfires. What remained was the chaparral ecosystem based on drought-tolerant, fire-adapted plants.

Were the megafauna collapse and a change in ecology results of a climatic harbinger for the Younger Dryas cool millennium, or some other cause? Interestingly, tangible evidence for the Clovis hunting culture of North America, which has long been implicated in the faunal 'extirpation', does not appear until 12.9 ka, and in California neither does any implicating other human groups. Yet evidence is accumulating for much earlier entry of humans into North America. Occupation sites are very rare on land, but human presence here and there implies such earlier migration, probably along the west coast that avoided the frigid interior further north than California. The question posed by OKeefe *et al*. is, 'Were the fires ignited by humans over a 300 year period just before the Younger Dryas'? It remains to be

confirmed … First human arrivals coinciding with evidence for wildfires in Australia, New Zealand and a few other areas do suggest that it is a possibility. There needs to be a motive, such as producing lush clearings in forest to attract game, or removing cover to make hunting easier. In this case, the fires immediately preceded a global climatic downturn with terrestrial drying, so they may have had natural causes: the potentially incendiary chaparral flora had been increasing steadily beforehand and decreased rapidly *after* the evidence for wildfires

See also: Price, M. 2023. Death by fire. *Science*, v. **381**, p. 724-727;
DOI: 10.1126/science.adk3291

A book on archaeology, radiocarbon dating, ancient DNA, and how modern humans evolved

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Since 2001 Tom Higham, now Professor of Scientific Archaeology at the University of Vienna, helped develop new ways of refining radiocarbon dating at Oxford University's Research Lab for Archaeology and the History of Art. Specifically his lab learned how to remove contamination of ancient samples by recent carbon and to reduce the detection limit of their accelerator mass spectrometer for the ^{14}C atoms that remained from when they were in living organisms. The Oxford Radiocarbon Accelerator Unit pushed sample dates to the absolute limit of the method: around 50 thousand years. Being among the very best, the ORAU had a path beaten to its doors by archaeologists from across the world keen to get the most believable dates for their samples. Equally, Higham engaged in the field work itself and in the interpretation of other data from sites, such as ancient DNA. An outcome of Higham's energetic efforts over two decades is his book *The World Before Us: How Science is Revealing a New Story of Our Human Origins* (paperback edition 2022, Penguin Books,ISBN-10: 0241989051). One reviewer commented 'The who, what, where, when and how of human evolution'.

The World Before Us is not only comprehensive and eminently clear for the lay-reader, but it is more exciting than any science book that I have read. For the moment, it is the latest 'word' on early, anatomically modern humans and on the closely related Neanderthals and Denisovans. Its core is about how these three key groups 'rubbed along' once they met in the Late Pleistocene. As an amateur interested in palaeoanthropology, I have tried to keep pace with all the developments in the field since 2001 through Earth-logs, but Higham shows just how much I have missed that is important to the human story. If you have followed my many posts on human evolution and migrations with interest, read his book for a great deal more and a coherent story of how things stand.

Sudden climate change: a warning from 8 millennia ago

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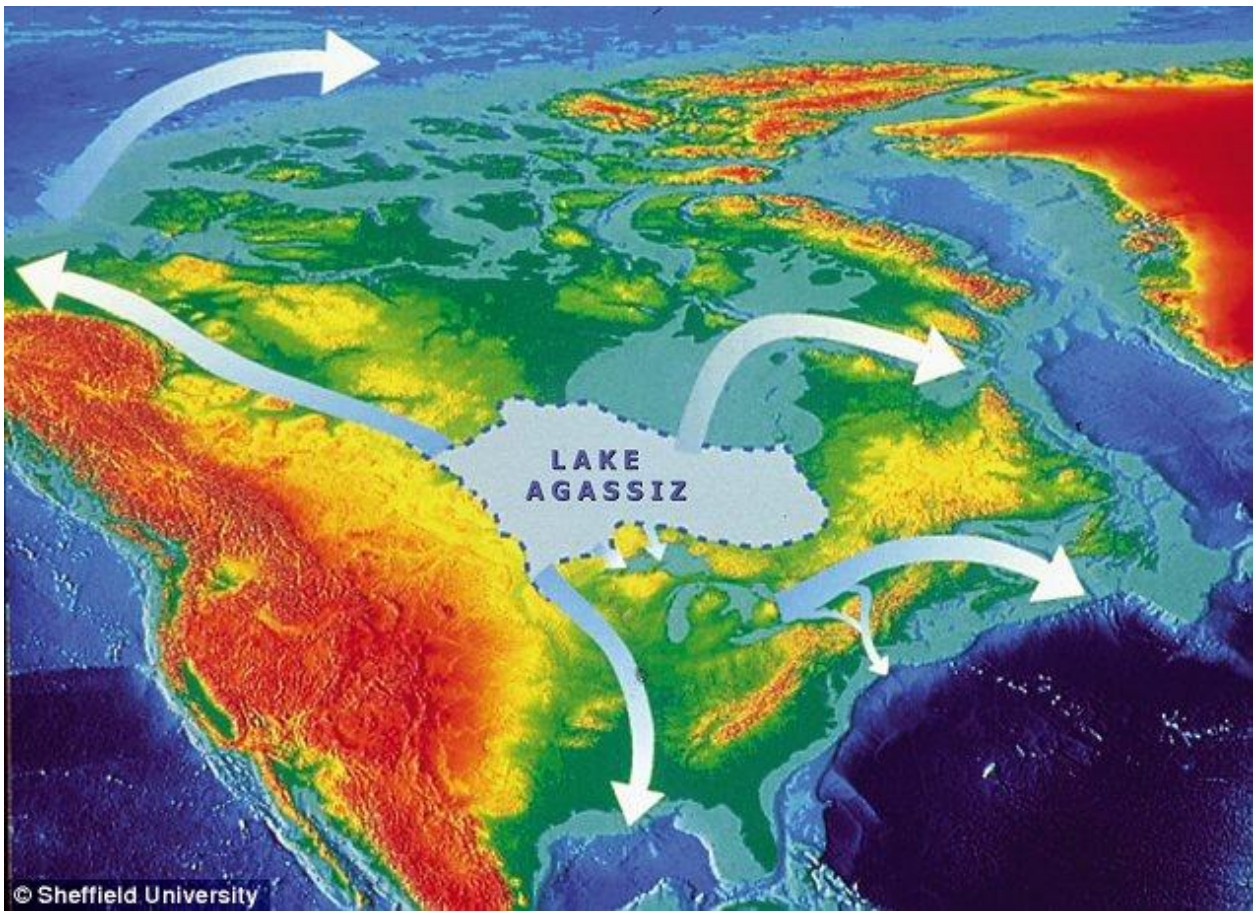
Mesolithic hunter-gatherers in Britain must have had a very hard time around 8.2 thousand years age. The whole area around the North Atlantic experienced sudden climatic cooling of around 3.3°C together with drought that lasted about 70 years. To make things worse shortly afterwards, coasts around the North were devastated by a tsunami generated by a submarine landslide off western Norway. That event exceeded the maximum coast 'run up' of both the 26 December 2004 Indian Ocean tsunami and that in NW Japan on 11 March 2011. Doggerland, then in the central North Sea was devastated by a catastrophic event of a few days duration. It littered the seabed with the bones of its megafauna and even Mesolithic tools recovered by trawlers from its surviving relic the shallow Dogger Bank. It seems the tsunami arrived just as climate was warming back to 'normal' Holocene conditions: for many foragers, surely, a last straw.

The cooling episode has been attributed to perturbation of the Atlantic Meridional Overturning Circulation (AMOC) as a result of meltwater discharge during the deglaciation of the Laurentide Ice Sheet (see: Just when you think it's going to turn out alright… November 2009).The event may have unfolded in a similar fashion to the trigger for the Younger Dryas and the succession of warming-cooling episodes known as Dansgaard-Oeschger events that interrupted the otherwise relentless global cooling towards the last glacial maximum (see: Review of thermohaline circulation; February 2002). The physics that set off such climatic 'hiccups' is that freshening of surface seawater reduces its density, so that it cannot sink to be replaced by denser saline water 'dragged' northwards from warmer latitudes. That currently takes the form of the Gulf Stream with its warming influence, particularly in the eastern North Atlantic and even beyond Norway's North Cape, responsible for much warmer winters than at similar latitudes on the western side. The culprit had long been suggested to be the drainage of a huge lake dammed by the ice sheet that covered most of eastern Canada during late stages of deglaciation. Seemingly the best candidate was Lake Agassiz trapped by the early Holocene ice front in Manitoba – the largest proglacial lake known anywhere.

The present landforms of central Canada show evidence for several outflow directions at different times, Including to the northwest to reach the Arctic Ocean at the onset of the Younger Dryas. Until recently there was little detailed evidence for the flow volume and timing of its drainage around 8 to 9 ka. Providing the details in the context of the short-lived event around 8.2 ka requires accurate data over a mere 200 years able to reveal a change in sea level to a precision of better than a few tens of centimetre. Any site on the shores of the North Atlantic would do, provided it satisfies these criteria. Geographers from

universities in York, Leeds, Sheffield and Oxford, UK selected the small estuary of the River Ythan in NE Scotland. There, a continuous sand unit just above fine-grained intertidal tidal muds marks the knife-sharp time datum of the Storegga tsunami (Rush, G. *et al*. 2023. The magnitude and source of meltwater forcing of the 8.2 ka climate event constrained by relative sea-level data from eastern Scotland. *Quaternary Science Advances*, v. **12**, article 100119; DOI: 10.1016/j.qsa.2023.100119).



Colour coded topographic elevation of North America showing the maximum extent of Lake Agassiz and four possible routes for its drainage: north-west to the Arctic Ocean via the Mackenzie River; south to the Gulf of Mexico via the Mississippi valley; east to the North Atlantic via the Great Lakes and St Laurence River; north to the North Atlantic via Hudson Bay. (Credit: ©Sheffield University)

Cores of the intertidal sediments from beneath the present Ythan salt marsh contain plant remains that yielded precise radiocarbon dates at several stratigraphic levels from which to derive an age-depth model for the age range of interest. The buried sediments are also rich in marine microfossils (foraminifera and diatoms) that thrive in estuaries at a variety of depths. These enabled fluctuations in relative sea level during the build-up of the intertidal sediments to be constrained at unprecedented resolution and precision for a three thousand year period from 9.5 to 6.5 ka. The authors show that there were two episodes of

rapid sea-level rise over that time: between 8.53 and 8.37 ka (~2.4 m at 13 mm yr^{-1}) and 8.37 to 8.24 ka (~ 0.6 m at 4 mm yr^{-1}) – these would have been *global* increases in sea level.

Despite its vast size, it turns out that Lake Agassiz would have been unable to result in sea-level rises of that magnitude so quickly merely through outflow. Rush *et al*. suggest that the huge and rapid addition of fresh water to the North Atlantic involved flow of lake water towards Hudson Bay, *beneath* the ice sheet, causing it to collapse and melt, followed by completion of Lake Agassiz's emptying in the second stage. It took a long drawn-out 'freshening' of the North Atlantic surface water ultimately to shut down the Atlantic Meridional Overturning Circulation, thereby depriving high latitudes of its east-side warming effect by the Gulf Stream.

Sea level has been rising since the early 20th century mainly through the melting of Greenland's ice cap together with a substantial amount of thermal expansion while global climate has been warming. Between 1901 and 2018 the rise has amounted to 15 to 25 cm at a rate of 1 to 2 mm yr^{-1}. The AMOC is possibly weaker now than at any time during the last millennium (Zhu, C. *et al.* 2023. Likely accelerated weakening of Atlantic overturning circulation emerges in optimal salinity fingerprint. *Nature Communications*, v. **14**, article 1245; DOI: 10.1038/s41467-023-36288-4). Yet increases in freshening of the northernmost parts of the North Atlantic are now being added to by annual increases in the melting of polar sea ice, which is salt-free. The AMOC may be approaching a tipping point, because warming is accelerating over Greenland at around 1.5°C each year: faster than most of the rest of the world. In 2021 it rained for the first time ever recorded at the ice cap's summit (3.2 km above sea level). A 'perturbation' of the AMOC would add chaos to the dominantly linear view of global warming taken by climatologists. That could launch frigidity and drought at mid northern latitudes as it did eight millennia ago: the opposite of what is currently feared.

See also: Unlocking Ancient Climate Secrets – Melting Ice Likely Triggered Climate Change Over 8,000 Years Ago. *Scitechdaily* 16 September 2023.

An evolutionary bottleneck and the emergence of Neanderthals, Denisovans and modern humans

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The genetic diversity of living humans, particularly among short, repetitive segments of DNA, is surprisingly low. As they are passed from generation to generation they have a high chance of mutation, which would be expected to create substantial differences between geographically separated populations. In the late 1990s and early 2000s some researchers attributed the absence of such gross differences to the human gene pool having been reduced to a small size in the past, thereby reducing earlier genetic variation as a result of increased interbreeding among survivors. They were able to assess roughly when such

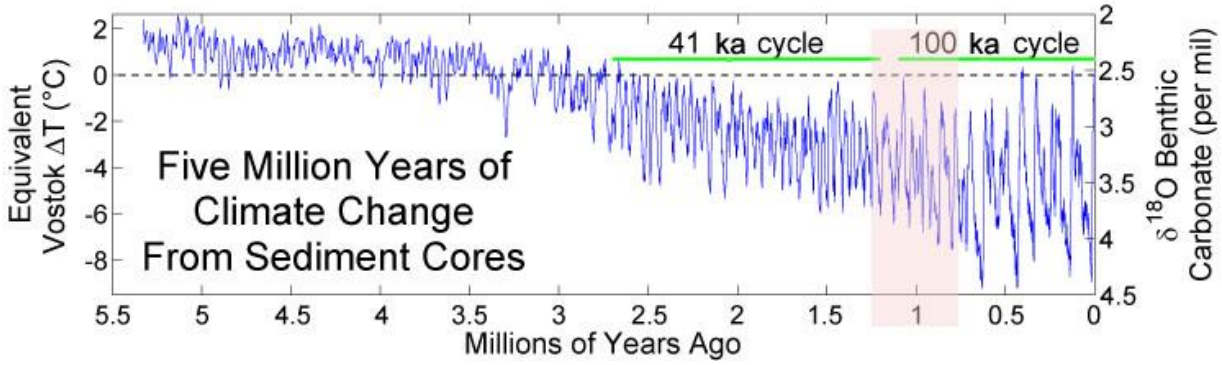
a population 'bottleneck' took place and the level to which the global population fell. Genetic analysis of living human populations seemed to suggest that around 74 ka ago the global human population fell to as little as 10 thousand individuals. A potential culprit was the catastrophic eruption of the Toba supervolcano in Sumatra around that time, which belched out 800 km^3 of ash now found as far afield as the Greenland and Antarctic ice caps. Global surface temperature may have fallen by 10°C for several years to decades. Subsequent research has cast doubt on such a severe decline in numbers of living hummans; for instance archaeologists working in SE India found much the same numbers of stone tools above the Toba ash deposit as below it (see: Toba ash and calibrating the Pleistocene record: December 2012). Other, less catastrophic explanations for the low genetic diversity of modern humans have also been proposed. Nevertheless, environmental changes that placed huge stresses on our ancestors may repeatedly have led to such population bottlenecks, and indeed throughout the entire history of biological evolution.

An improved method of 'back-tracking' genetic relatedness among living populations, known as fast infinitesimal time coalescence or 'FitCoal', tracks genomes of individuals back to a last common ancestor. In simple language, it expresses relatedness along lineages to find branching points and, using an assumed mutation rate, estimates how long ago such coalescences probably occurred. The more lineages the further back in time FitCoal can reach and the greater the precision of the analysis. Moreover it can suggest the likely numbers of individuals, whose history is preserved in the genetics of modern people, who contributed to the gene pool at different branching points. Our genetics today are not restricted to our species for it is certain that traces of Neanderthal and Denisovan ancestry are present in populations outside of Africa. African genetics also host 'ghosts' of so-far unknown distant ancestors. So, the FitCoal approach may well be capable of teasing out events in human evolution beyond a million years ago, if sufficient data are fed into the algorithms. A team of geneticists based in China, Italy and the US has recently applied FitCoal to genomic sequences of 3154 individual alive today (Hu, W.and 8 others 2023. Genomic inference of a severe human bottleneck during the Early to Middle Pleistocene transition. *Science*, v. **381**, p. 979-984; DOI I: 10.1126/science.abq7487). Their findings are startling and likely to launch controversy among their peers.

Their analyses suggest that between 930 and 813 ka ago human ancestors passed through a population bottleneck that involved only about 1300 breeding individuals. Moreover they remained at the very brink of extinction for a little under 120 thousand years. Interestingly, the genetic data are from people living on all continents, with no major differences between the analyses for geographically broad groups of people in Africa and Eurasia. Archaeological evidence, albeit sparse, suggests that ancient humans were widely spread across those two continental masses before the bottleneck event. The date range coincides with late stages of the Mid-Pleistocene climatic transition (1250 to 750 ka) during which glacial-interglacial cycles changed from 41 thousand-year periods to those that have an average

duration of around 100 ka. The transition also brought with it roughly a doubling in the mean annual temperature range from the warmest parts of interglacials to the frigid glacial maxima: the world became a colder and drier place during the glacial parts of the cycles.

Genomes for Neanderthals and Denisovans suggest that they emerged as separate species between 500 and 700 ka ago. Their common ancestor, possibly *Homo heidelbergensis*, *H. antecessor* or other candidates (palaeoanthropologists habitually differ) may well have constituted the widespread population whose numbers shrank dramatically during the bottleneck. Perhaps several variants emerged because of it to become Denisovans, Neanderthals and, several hundred thousand years later, of anatomically modern humans. Yet it would require actual DNA from one or other candidate for the issue of last common ancestor for the three genetically known 'late' hominins to be resolved. But Hu *et al*. have shown a possible means of accelerated hominin evolution from which they may have emerged, at the very brink of extinction.



Oxygen-isotope record and global temperature changes over the last 5 million years, green lines showing the times dominated by 41 and 100 ka climatic cycles. The mid-Pleistocene climatic transition is shown in pink (Credit: Robert A Rohde)

There is a need for caution, however. *H. erectus* first appeared in the African fossil record about 1.8 Ma ago and subsequently spread across Eurasia to become the most 'durable' of all hominin species. Physiologically they seem not to have evolved much over at least a million years, nor even culturally – their biface Acheulean tools lasted as long as they did. They were present in Asia for even longer, and apparently did not dwindle during the mid-Pleistocene transition to the near catastrophic levels as did the ancestral species for living humans. The tiny global population suggested by Hu *et al*. for the latter also hints that their geographic distribution had to be very limited; otherwise widely separated small bands would surely have perished over the 120 ka of the bottleneck event. Yet, during the critical period from 930 to 813 ka even Britain was visited by a small band of archaic humans who left footprints in river sediments now exposed at Happisburgh in Norfolk. Hu *et al*. cite the scarcity of archaeological evidence from that period – perhaps unwisely – in support of their bottleneck hypothesis. There are plenty of other gaps in the comparatively tenuous fossil and archaeological records of hominins as a whole.

The discovery of genetic evidence for this population bottleneck is clearly exciting, as is the implication that it may have been the trigger for evolution of later human species and the stem event for modern humans. Hopefully Hu *et al*'s work will spur yet more genetic research along similar lines, but there is an even more pressing need for field research aimed at new human fossils from new archaeological sites.

See also: Ashton, N. & Stringer, C. 2023. Did our ancestors nearly die out? *Science* (Perspectives), v. **381**, p. 947-948; DOI: 10.1126.science.adj9484.

Ikarashi, A. 2023. Human ancestors nearly went extinct 900,000 years ago. *Nature*, v. 621; DOI: *10.1038/d41586-023-02712-4*

Di Vicenzo, F & Manzi, G. 2023. An evolutionary bottleneck and the emergence of Neanderthals, Denisovans and modern humans. Homo heidelbergensis as the Middle Pleistocene common ancestor of Denisovans, Neanderthals and modern humans. *Journal of Mediterranean Earth Sciences*, v, **15**, p. 161-173; DOI: 10.13133/2280-6148/18074

Extreme scientific showing-off: Hominin fossils in space

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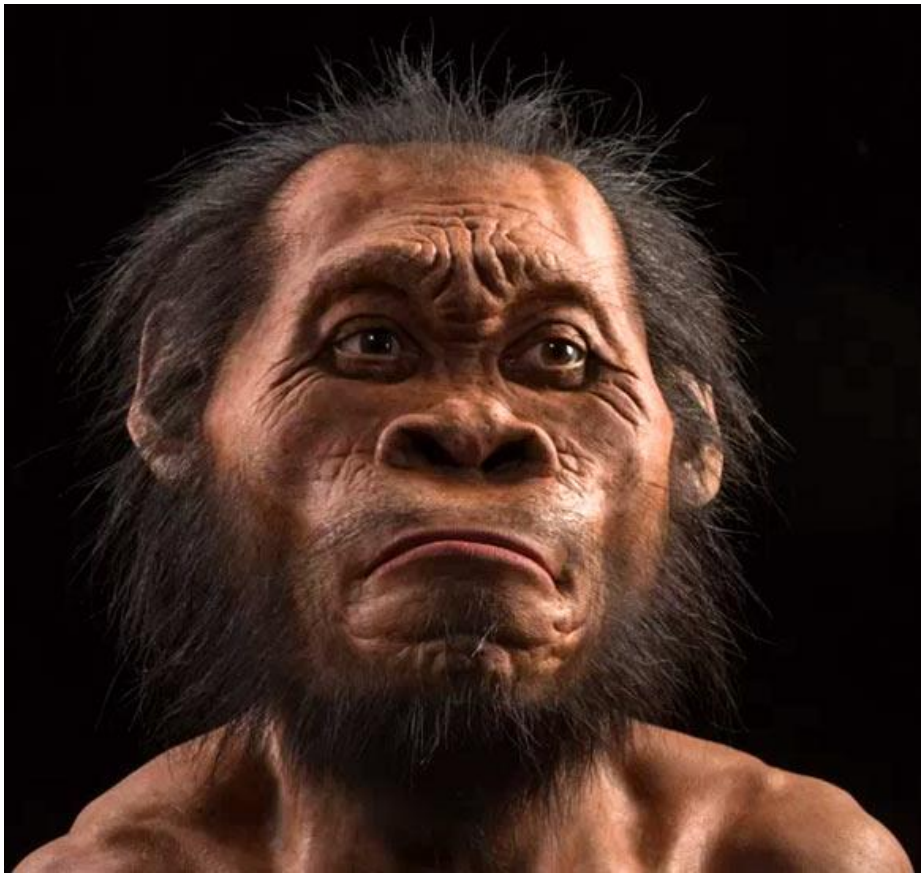
Good illustrations of self publicity and soaring ambition are the private space programmes of oligarchs Elon Musk (SpaceX), Jeff Bezos (Blue Origin) and Richard Branson (Virgin Galactic). For a cool US$ 65 million a 'civilian' can get a trip to the International Space Station on SpaceX; a one-hour suborbital flight on Blue Origin will cost US$300,000, with luck having Bezos as a companion; a reservation on Virgin Galactic for a 1 hour trip to the 'edge of space' (~100 km up) now costs US$624,000. It's a tourist trip for the very, very rich only … but even the long-dead can go … or bits of them. On 8 September 2023 aboard Virgin Galactic flight Tim Nash, a South African billionaire had in his pocket *a sturdy tube containing* a thumb bone of *Homo naledi* and the collarbone of *Australopithecus sediba*. Nash reportedly said afterwards, "I am humbled and honoured to represent South Africa and all of humankind as I carry these precious representations of our collective ancestors".



Reconstructed head of a somewhat annoyed Homo naledi. Credit: John Gurche, Mark Thiessen, National Geographic.

Nash was entrusted with these unique fossils by Lee Berger, Professor in Palaeoanthropology at Witwatersrand University, South Africa and a National Geographic Explorer-in-Residence. Berger recovered fossils of both species from limestone caves in the UNESCO World Heritage Site grandly named the Cradle of Humankind near Johannesburg. He is no stranger to controversy, and this venture cooked up with Nash seems to aim at promotion of South African achievements rather than having any scientific purpose. It has backfired spectacularly (see: McKie, R. 2023. 'Callous, reckless, unethical': scientists in row over rare fossils flown into space. *The Observer*, 22 October 2023). Comments from the anthropological world, six national and international bodies and perhaps the leading hominin specialist Professor Chris Stringer of the Natural History Museum in London include the words and phrases "callous", "unethical", "extraordinarily poorly thought-out", "a publicity stunt", "reckless" and "utterly irresponsible". The caper breaks the South African, indeed international, scientific rule that fossils can only be allowed to travel for scientific purposes, applied consistently by similarly hominin-rich African countries such as Ethiopia, Kenya and Tanzania.

But, Hey, that's how you get on in the world … isn't it?

North America occupied by modern humans during the Last Glacial Maximum

PUBLISHED ON *October 20, 2023*

White Sands National Park in New Mexico, USA is notorious for being adjacent to the site at which the first nuclear weapon was tested (code name Trinity) on 16 July 1945. Four weeks later two such bombs killed between 129,000 and 226,000 people at Hiroshima (6 August 1945) and Nagasaki (9 August 1945). The area is one of spectacular geology, the white sand being made of gypsum ($CaSO_4$) grains precipitated from lake water supplied by rivers that had dissolved the mineral from Permian evaporites in the surrounding mountains. Subsequent wind erosion created a large, white dune field: the main attraction. Though a national park that has been proposed for UNESCO World Heritage Centre, the park itself is surrounded by military installations including the nuclear test site.

Gypsum sand dunes in White Sands National Park USA. (Credit: Wikipedia)

As in most evaporite basins, the White Sands' gypsum sediments built up layer-by-layer through deposition of clays during successive inundations followed by evaporation of $CaSO_4$ rich water. Animals crossing the basin were likely to leave trackways, which subsequent sedimentary cycles could preserve in stratigraphic order. Examples had been found in the early 20th century, revealing the former presence of the late-Pleistocene megafauna: Columbian mammoths, ground sloths, ancient camels, dire wolves, lions, and sabre-toothed cats. One set of dire wolf prints found in the 2010s contained seeds that yielded a radiocarbon age of 18 ka. More recently, 61 human footprint tracks turned up in layers that also displayed signs of megafauna crossing the lake flats, in one case showing convincing signs of hunters having followed a giant ground sloth (Bennett, M.R. 2021 and 13 others 2021. Evidence of humans in North America during the Last Glacial Maximum. *Science*, v. **373**, p. 1528-1531; doi: 10.1126/science.abg7586). Interestingly, many of the human tracks seem to have been made by teenagers and children with only a few made by adults. Dating of seeds in the sediment layers – and in some footprints –

yielded 23 to 21 ka radiocarbon ages. This evidence suggested human occupation of New Mexico long before those who left Clovis-style artifacts around 13 ka and others who preceded them. However, the seeds that were dated are those of an aquatic grass (*Ruppia cirrhosa*), which may have absorbed older carbon from groundwater permeating the evaporite sediments. Being robust, the seeds could also have been transported by wind back and forth from plants that lived before the animals and humans left their marks in the saline flats. Such is the importance of the White Sands fossil trackways that a team of US and British geologists, some of whom authored Bennett *et al*. 2021, have sought to refute doubts of their antiquity (Pigati, J.S. and 10 others 2023. Independent age estimates resolve the controversy of ancient human footprints at White Sands. *Science*, v. **382**, p. 73-75; DOI: 10.1126/science.adh5007).

Human footprints (arrowed) preserved on three sediment surfaces of the White Sands clay-gypsum sequences; i.e. at three times in their depositional sequence. (Credit: from Pigati et al.; Fig 1)

The researchers cut trenches into the layered clay-gypsum to reveal human footprints on three successive surfaces at the site where *Ruppia* seeds had provided very old, but disputed ages. They supplemented the earlier evidence by ^{14}C dating of pollen grains blown into the prints from terrestrial plants and optically stimulated luminescence ages (time of last exposure to sunlight) of detrital quartz grains in the evaporites. The pollen dating gave ages from 23.4 to 22.6 ka, the minimum quartz OSL age being 21.5 ka. Similar ages from three different methods are pretty convincing evidence that humans were active in New

Mexico during the Last Glacial Maximum (LGM), and that absorption of older carbon from groundwater had not affected the *Ruppia* seeds.

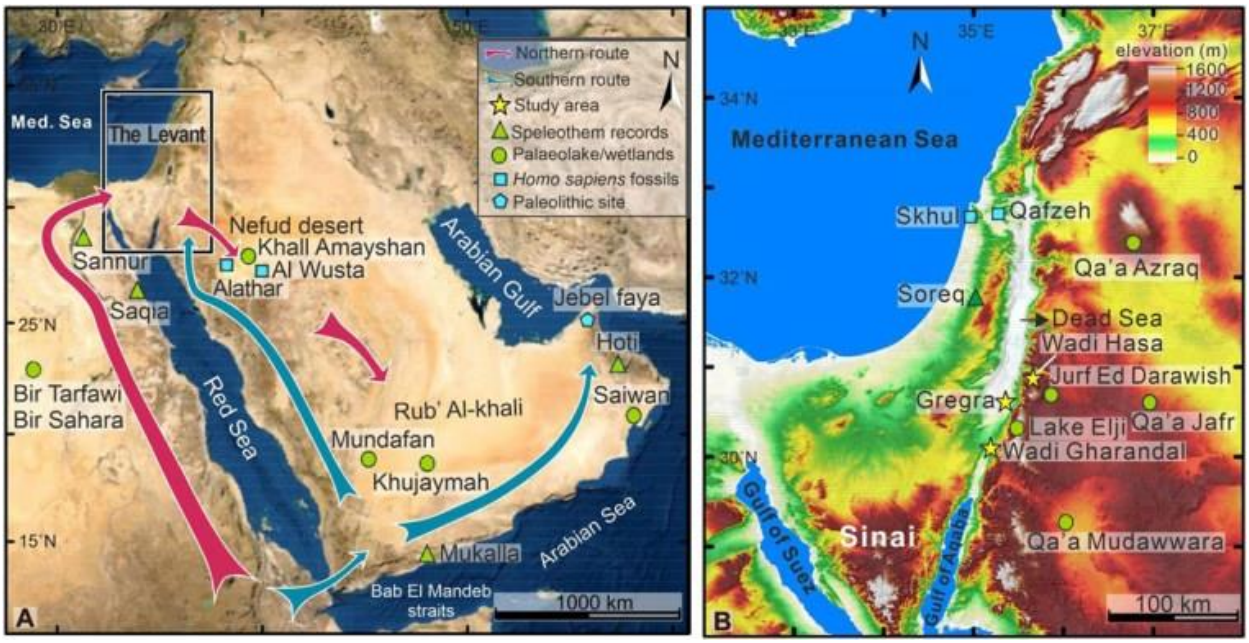
The Asia to America migration, which led these hunters to what the abundant megafauna trackways suggest were rich pickings around the White Sands palaeo-lake, must have been earlier still. High-latitude North America was almost certainly a vast, frigid desert for thousands of years leading up to the LGM. Another implication of the remarkable finds in the gypsum beds is that migration most probably involved a coastal or even a maritime route along the Eastern Pacific shore to reach more habitable lower latitudes.

See also: Earliest Americans, and plenty of them. *Earth-logs*, 27July 2020; Prillaman, M. 2023. Human footprints in New Mexico really may be surprisingly ancient, new dating shows. *Science News*, 5 October 2023.

A way for early humans to leave Africa for Eurasia via the Middle East

PUBLISHED ON *October 9, 2023*

Without seafaring skills and sturdy boats, ancient humans had only two options to leave Africa for Eurasia: by crossing the Straits of Bab el Mandab at the southern end of the Red Sea and from the Nile delta to the Levant at its northern end. Both would have been difficult. The first route demanded extremely low sea level drawn down by continental ice accumulation to narrow the sea crossing, the earliest in the last glacial cycle being around 70 ka ago. The northern route, with no sea crossing, was potentially achievable throughout the history of the genus *Homo*. But that way is beset to the north and east by deserts with large tracts that today lack natural water sources. To leave Africa by that route seems the most obvious, being reached along the well-watered Nile valley or the Red Sea coast with its abundant marine resources. Yet moving eastwards to Arabia and further would have required climatic windows of opportunity to ensure well-watered corridors: it would be impossible today without an infrastructure of wells; and edible resources are extremely sparse. Remains of anatomically modern humans (AMH) as old as 200 ka and others in the period between 130 to 85 ka have been found around the eastern shores of the Mediterranean. Either of the two routes could have led them there during periods of increased humidity, perhaps in a series of migratory pulses. In the case of an exodus across the Straits of Bab el Mandab, people could have moved northwards along the Red Sea coast of modern Yemen and Arabia to the Levant. However, the record is patchy, and there is no direct fossil evidence to suggest they went further, into southern Asia or Europe in these earlier times. Each early venture may also have ended in extinction. The first presence of AMH in Asia and Europe, seems to have been tens of thousand years later: about 75 ka and 45 ka, respectively, so far as we know.



Left: Satellite image of the Arabia and the Levant, showing the possible northern (red) and southern migration routes (blue) and sites that yielded various palaeoclimatic signs of formerly wet areas, Homo sapiens fossils and stone tools (see key). **Right** colour-coded map of topographic elevation for the study area in the Levant with sites that reveal palaeoclimatic and anthropological information. (Credit: Abbas et al., Fig 1)

Research in the Arabian Peninsula has early recorded human presence from discarded stone artefacts at widely scattered sites, as far east as the UAE and Oman, but whether these were carried by AMH or other human groups is uncertain. Yet geological research suggests that even in the presently forbidding Empty Quarter of Saudi Arabia there were from time to time abundant springs, river networks and even lakes: occasionally climate changes made much of Arabia habitable. Researchers from the University of Southampton (UK) and Shantou University (China), together with colleagues in Jordan, Australia and the Czech Republic have documented further evidence for 'green' episodes on the Jordan Plateau – part of the currently hyperarid Arabian interior (Abbas, M. and 10 others 2023. Human dispersals out of Africa via the Levant. *Science Advances*, v.**9**, article eadi6838; DOI: 10.1126/sciadv.adi6838).

Three sites in Jordan reveal wetland sediments incised by now dry channels or *wadis*, one of which yielded stone tools Luminescence dating of wetland sediment grains shows the times when they were last exposed to sunlight: some between 86 to 65 ka, others between 57 to 43 ka. Together with data from the rest of Arabia the sites help roughly to define routes that would have permitted human migration, though not the actual directions that early AMH might have travelled or their destinations – if any. They may just have wandered around surviving on the resources that they found during short periods of amenable local climate, and vegetation much as do desert dwellers today. Actually to exit Arabia to southern Asia would require migration around what is now the Persian Gulf, where relevant data are lacking and likely to remain so while poor security for research prevails. To get to Europe

would require a much more intricate journey through large mountainous tracts to reach the shores of the Black Sea.

See also: Early human migrants followed lush corridor-route out of Africa. *Science Daily*. 4 October 2023